Large Reinforced Concrete Piles Prove More Economical

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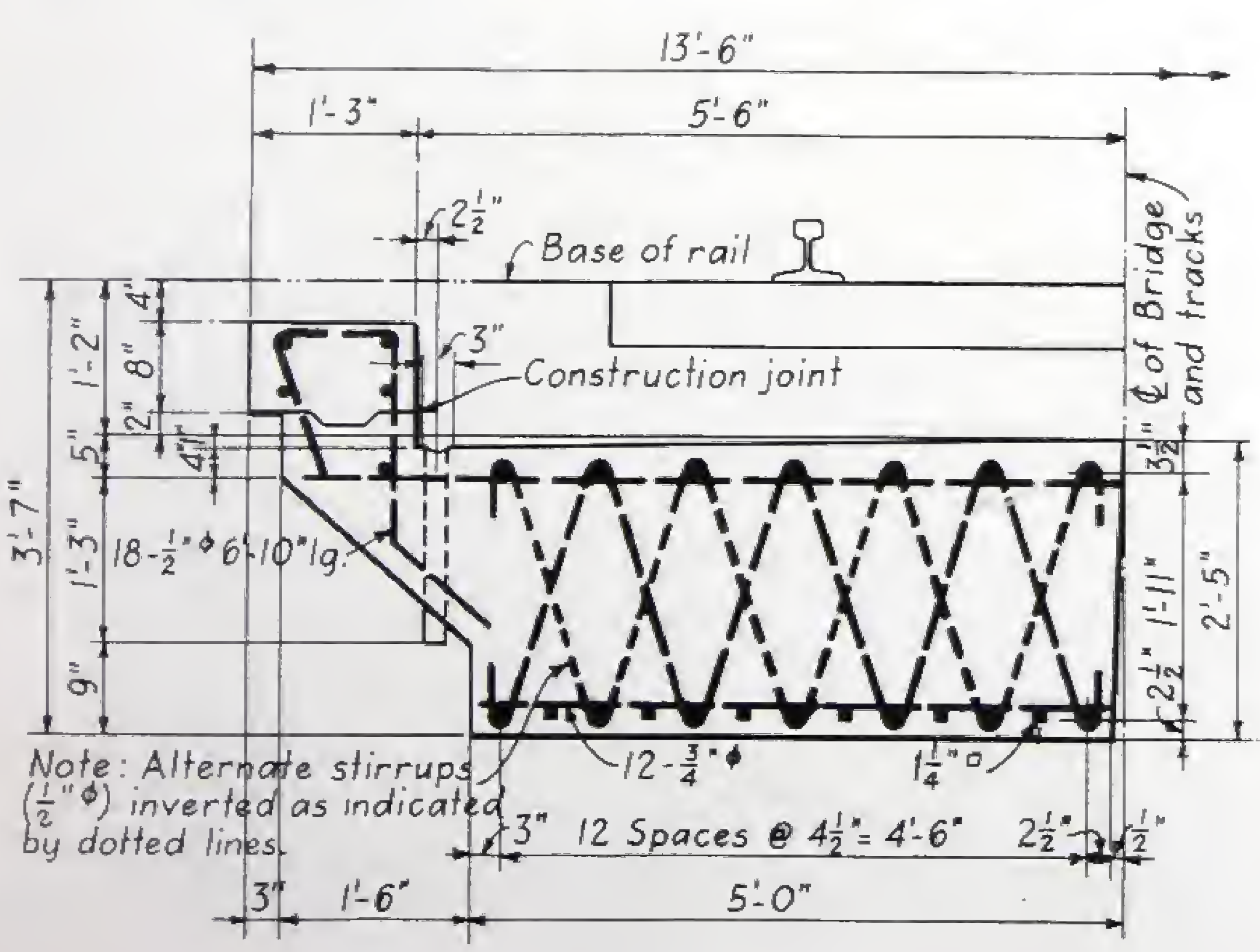
Large Reinforced Concrete Piles Prove More Economical

Missouri Pacific has applied 5,000 of them after demonstrating special advantages of the three-pile bent

Above—Three 24-in. Piles Set and Driven Without Disturbing the Stringers

Accurate Setting of the Piles Is Assured By Digging Holes at the Site of Each Bent and Constructing Heavy Timber Frames

THE experience of the Missouri Pacific in the construction of trestle structures involving the use of reinforced concrete piles 24 in. in diameter has demonstrated economies for concrete in this particular application greatly exceeding those attainable with earlier designs. Concrete pile trestles built heretofore have constituted imitations of the wooden pile trestle, involving the use of piles not more than about 16 in. in diameter. While the use of larger piles has made it possible to reduce the number per bent and has thus effected a corresponding economy in the number of piles to be driven, the outstanding advantage realized from the use of larger piles arises from the development of the three-pile bent, which possesses an advantage over bents containing any greater number of piles that is not measured by the mere reduction in number.



Cross Section of An 18-ft. Slab

The vast majority of railway bridges built today are constructed to replace older bridges. Therefore, the construction of a pile trestle almost invariably involves the driving of the piles through the deck of the old bridge, and in the driving of four, five or six-pile bents, at least two of the piles of each bent cannot be driven without shifting the stringer chords. As a result, except on lines of exceedingly light traffic, a large part of the time of the driving crew is occupied in shifting the deck—either to open it to permit driving, or to close it to enable trains to pass. The three-pile bent eliminates this difficulty, since with only three piles it is possible to space them in the bent so as to clear the chords entirely. The only preparatory work necessary, so far as the bridge deck is concerned, is to shift three ties, and since these ties can be quickly replaced, the principal precaution imposed on the pile-driver crews in avoiding interference with trains is to make sure that the driving of no pile is started without ample time to

The Piles Are Used Primarily for Reinforced Concrete Slab and Steel-Beam Spans

complete it in advance of the arrival of a train. That this advantage of the three-pile bent is a real one, is clearly shown by the experience of the Missouri Pacific, where the proportion of the time of driver crews that is lost in clearing for traffic on the new concrete pile trestles is but a fraction of the normal unproductive time of a driving outfit engaged in work involving the shifting of stringer chords.

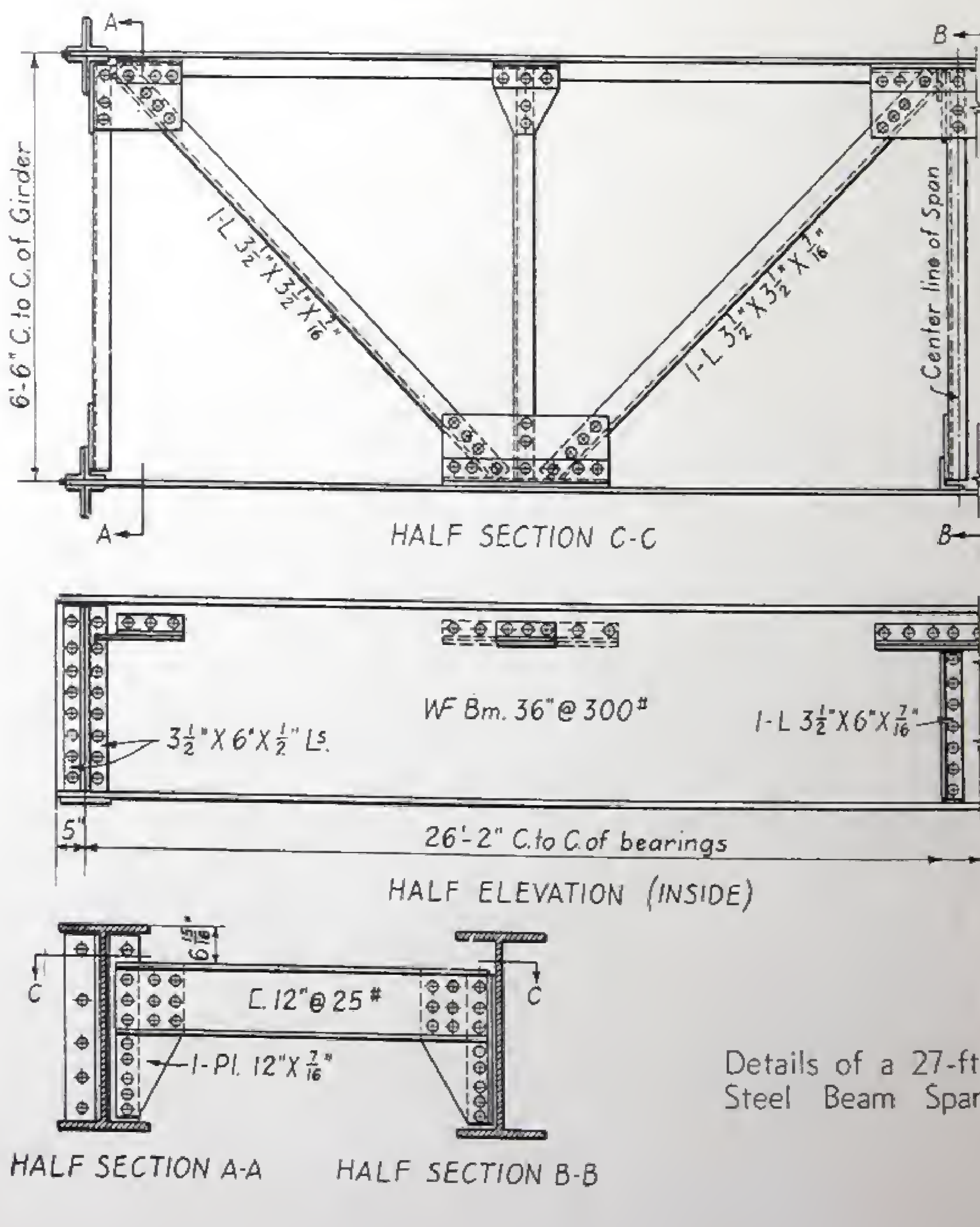
Investigate Bearing Power

The problems presented in the design of this new type of construction, including an account of the loading tests conducted by the Missouri Pacific to determine the relative load-carrying capacity of the 24-in. piles, compared with piles of ordinary dimensions, were reviewed in an article in the *Railway Age* of February 10, 1934, page 220, which was written by F. E. Bates, bridge engineer of the Missouri Pacific, under whose direction this development was carried out. But like all other innovations, many practical problems of construction had to be solved before it was possible to develop the requisite technic for the effective and economical manufacture, shipment and driving of the piles. However, experience in the use of some 5,000 of these piles in new bridges on the Missouri Pacific during the last three years has afforded ample opportunity for the perfection of construction methods and for a demonstration of the inherent economies of this new type of construction.

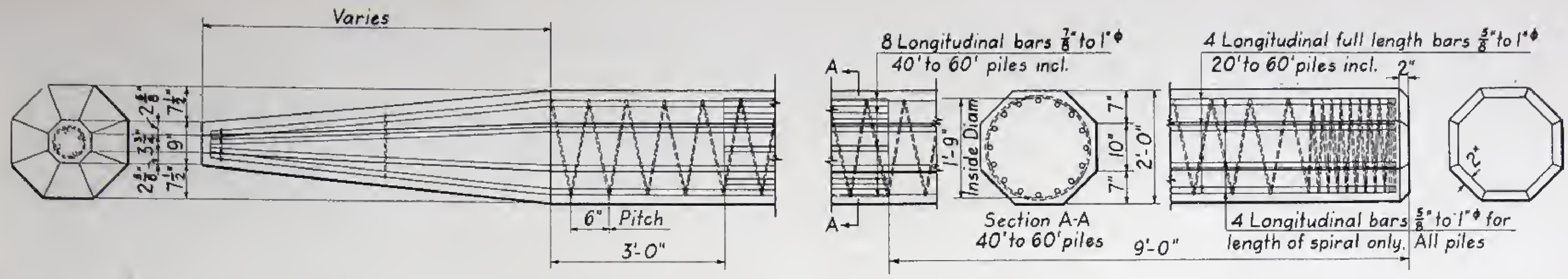
These large reinforced concrete piles have been used primarily in two types of structures, namely, all-concrete structures in which the bents serve as the supports for reinforced concrete slabs that carry ballasted track, and steel-beam spans that are generally provided with an open deck, although some of them have been built with a creosoted-timber ballast deck. In addition, these piles have been employed in groups of six or more to serve as piers for plate girder spans. The panel lengths for concrete slab structures range from 15 to 18 ft., while the steel spans, because of their smaller dead load, are appreciably longer—usually either 24 or 27 ft. An important factor in the determination of the exact span lengths adopted is a bent spacing that will avoid interference with the bents of the old structure that is to be replaced.

The 24-In. Pile

The concrete pile developed by the Missouri Pacific has an octagonal section, 24 in. on the short diameter, and is tapered at one end for a length of 3 to 6 ft. to form a 9-in. octagonal tip. The reinforcement consists of longitudinal deformed rods from ⅝-in. to 1 in. in diameter, with spiral wrapping of No. 4 gage wire on a 6-in. pitch, except for 7 turns on a 2-in. pitch at the butt to resist the bursting stresses of driving. As in concrete piles of smaller diameter, beam strength to resist the stresses set up in handling, rather than the strength as a column, is the controlling factor in design. The strength in bending is about 2¼ times and



Details of a 27-ft. Steel Beam Span



Details of the Reinforced Concrete 24-in. Pile

the stiffness is 5 times that of a 16-in. pile. The maximum length of the piles driven to date is 60 ft., but splicing has been resorted to in numerous instances, as will be explained later.

The maximum height of the structures in which these concrete piles have been used is 30 ft., measured from base of rail to ground line. When this height exceeds 18 ft., double or anchor bents, described below, are introduced at intervals of about 150 ft. in long structures, and additional stiffness is provided by encasing the piles of each plant at the ground line in a concrete collar or sash brace 3 ft. wide and deep, and 13½ ft. long.

The piles of each bent are surmounted by a cap 3 ft. wide, 3½ ft. deep and 13½ ft. long for the single intermediate bents, and 6 ft. wide for the double or anchor bents provided at intervals in long, high structures. These larger caps cover the tops of two rows of piles 3 ft. center to center. The end bents are like the single intermediate bents, with the addition of back walls and short cantilevered wings, except when placed in new embankment, in which case a double row of piles, three in front and two in the rear, is used.

The Slab Structure

The superstructure for the reinforced concrete trestles consists of split slabs, i.e., two slabs per track, with a longitudinal joint along the center line of the tracks as well as between tracks. Slabs for single-track or for the outside rows on multiple-track bridges are only 5 ft. wide at the bottom, but have copings that project outward to a distance of 6 ft. 9 in. from the center line of the track, as well as 11 in. above the ballast-supporting surface. This arrangement results in a saving of 2.7 cu. ft. of concrete per lineal foot of slab, compared with a slab having a bottom width of 6 ft. 9 in. In an 18-ft. slab, this amounts to a reduction of 1.8 cu. yd. of concrete, and 3.6 tons in the weight. The 18-ft. slabs, the ordinary maximum length, have a depth of 2 ft. 5 in., so that with a vertical distance of 1 ft. 2 in. from base of rail to top of slab, these spans involve a total floor depth of 3 ft. 7 in. The 18-ft. slabs weigh 18½ tons.

Setting the Slabs Is a Simple Operation

The ballast-supporting surface is not provided with a complete waterproofing system, the treatment of the surface as a whole being confined to a coat of emulsified asphalt applied at the concrete plant, where the resulting sealing off of evaporation permits a reduction in the curing period. The tops of the slabs are also sloped laterally one inch from the edge under the center line of track for drainage, parapet slabs being provided with drain pipes at the low point.

To prevent leakage of water or ballast through the joints between slabs, both longitudinal and transverse, the tops of the slabs are recessed at these joints to form a depression one inch deep and about eight inches wide, into which a two-ply membrane waterproofing is applied with a protection consisting of an asphalt plank one inch thick. In addition, the space between the ends of slabs over the bents is filled with elastite.

The Beam Spans

The beam spans are constructed of wide-flange (CB-section) beams, two for each track, spaced 6 ft. between centers for open decks, and 6½ ft. between centers for timber ballast decks. The beam sizes range from 36-in. 230-lb. for 24-ft. open-deck spans, to 36-in. 300-lb. for 27-ft. ballasted spans. The bracing system, which has been designed to secure maximum simplicity of fabrication and avoid any holes in the beam flanges, as seen in the drawing, embodies three cross frames, one at each end and one at mid-span, and lateral bracing in one plane about 7 in. below the top flanges. The sole plates, ¾ in. thick, are attached to the bottom flanges of the beams by ½-in. fillet welds.

For protection against brine drippings, the top flanges of the beams are covered in the field with wrought iron plates 20 in. wide by $^{3}/_{16}$ in. thick, this width being sufficient to provide an overhang of 1⅝ in. beyond the edges of the beams. These projecting edges are bent down on curves of 2-in. radius to form drip edges.

The slabs and piles are manufactured in a concreting plant at Little Rock, Ark., and have been shipped to Missouri Pacific points as far as 800 miles from the plant. However, the out-of-pocket cost of the transportation is by no means proportional to the distance, where the movement is in the direction of light traffic.

The mix, for the aggregates used at Little Rock, is 1-2.4-3.6, and the strength of the concrete at 28 days ranges from 3,500 lb. to as much as 4,200 lb. per sq. in.

Bearing Power

Because the development of adequate bearing power is the critical element in the success of this type of structure, the driving of the piles has been a subject of intensive study, and in actual practice is conducted under the direction of experienced foremen who give it their personal attention, such other operations as are in progress simultaneously being supervised by the assistant foreman.

Analytical studies of the potential bearing power of the 24-in. piles were confirmed by a series of loading tests, as reported in the article by Mr. Bates previously referred to, the general conclusion being that under the same conditions the 24-in. pile has a bearing power roughly double that of a 16-in. pile. Loading tests are readily made during the driving of any trestle by blocking up the bridge deck on the middle pile of a bent and spotting the front truck of the pile driver crane over this pile. The load line of the crane is then made fast to a driven pile in a bent in front of the pile that is being tested, and when a strain is taken on the line, substantially the entire weight of the crane is concentrated on the test pile. The design load on the piles in the three-pile trestle bents is about 60 tons per pile, live load plus dead load; impact is not considered.

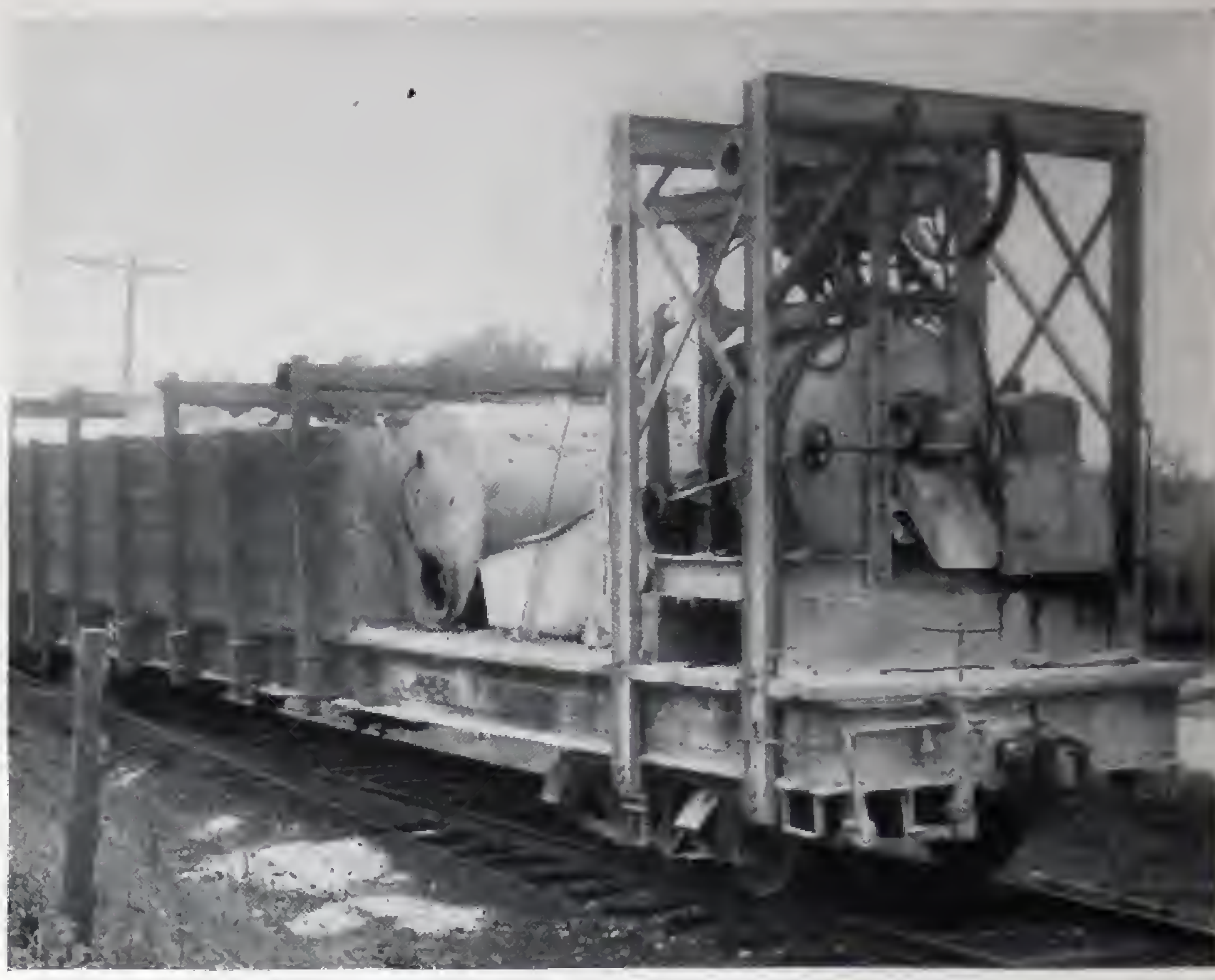
To develop the capacity of these larger piles requires a more powerful hammer, and after investigation the Vulcan No. 0 steam hammer with a 7,500-lb. ram was adopted for this work. For piles 40 ft. or more in length sufficient additional weight is applied to the ram to give a total weight of 9,000 lb. As the piles weigh about 500 lb. per foot of length and piles up to 60 ft. in length are driven, an essential requirement of the driving equipment is the safe and expeditious handling of loads of 15 tons, exclusive of the weight of the hammer and leads. Accordingly, the use of leads was dispensed with and the piles and hammer are handled by a locomotive crane. The Missouri Pacific uses two locomotive cranes in this service—one of 50 tons and the other of 30 tons capacity, both capable of traveling at 20 miles per hour.

To insure accurate placing of the piles, a hole from four to six feet deep is bored for each pile with an earth auger and a heavy timber guide frame is set over these holes and securely braced against the adjacent old bents. By this means and the exercise of care in plumbing the piles before the driving is started and in keeping the hammer in a vertical position, it has been possible to drive the piles with a high degree of accuracy. This preparatory work may be started some time in advance of the arrival of the driving outfit.

The top of the pile is cushioned during driving by a block of gum or oak, four to six inches thick that is inserted in the bonnet of the hammer. One block will drive from two to four piles, depending on driving conditions. A noticeable difference in penetration per blow is experienced with a fresh block and one that has been used to drive one or more piles, owing to the additional cushioning effect of the wood before it has been compressed. With this protection, shattering of the tops of the piles has been avoided.

Spliced or Cut to Length

The pile lengths are determined by driving timber test piles with a No. 2 Vulcan hammer and no difficulty is experienced in securing equal or greater penetration with the concrete piles. However, no complications are introduced in the event that it is found necessary to drive the piles to a greater depth or to discontinue driving at a less depth than that assumed in determining the length required. A pile can be readily cut off in 20 min. by notching the concrete with a jack hammer or hand tools to expose the bars, and then burning these off with a gas torch. As a matter of fact, it is the regular practice to leave the two outside piles of each bent 18 in. high and then cut away the concrete for that distance so that the exposed reinforcement will serve as an effective bond between the piles and the cap. A similar procedure in the case of piles that have to be over-driven affords the necessary bond for a splice between the pile and an extension concreted on top of it in the field. Such splices have been made in such a workmanlike manner that the joint is scarcely discernible.



The Car-Mounted Plant Used for Concreting the Caps

Owing to the reduction in time lost on account of interruptions to the work to permit trains to pass, the output of the driver in the driving operation is appre-

Cutting Off a Pile—The Concrete Is Cut Away So that the Bars May Be Burned Off with a Torch

ciably greater than is the case with six-pile bents. Typical of the performance is the driving of a maximum of eighteen 35-ft. piles per 8-hr. day to a penetration averaging 25 ft. through clay, sand and silt, with four interruptions for train movements. Where the interval between trains permits, as many as 9 piles have been set in place and then driven in a substantially continuous operation.

Concreting the Caps

The caps are concreted in sectional forms assembled around the tops of the piles and supported by means of heavy steel clamps that are bolted around the piles beneath the bottom form. The concreting is done with a mixing plant mounted on a flat car, and embracing a gas-driven Koehring 10-cu. ft. mixer placed at one end of the car so that it can be discharged directly into the forms, a water tank, and a bin for 20 cu. yd. of fine and coarse aggregates, together with storage space for enough cement to concrete four caps. The operation of this plant requires five men—a mixer operator, two men charging the mixer and two men in the form. On small jobs or on the last few bents of a long bridge, high-early-strength cement is sometimes used to avoid delay in the setting of the superstructure, which is done by the same force that has been employed in building the bents.

Setting the superstructure is a simple operation whether it involves the placing of concrete slabs or steel beam spans. The progress made depends on the traffic interference, but as many as ten panels of slabs have been set in one day, while on a trestle crossing of an overflow opening of the St. Francis river east of Poplar Bluff, Mo., ten 27-ft. beam spans were erected in one day. The operation is expedited by providing a light crane to remove the old timber deck, thereby permitting the crew of the large crane to devote its time exclusively to the handling of the new superstructure. The slabs are set on a bed of dry portland cement.

A typical gang for the construction of these pile trestles, including the pile driving, the concreting of the caps and the setting of the superstructure, is made up as follows:

1 foreman
1 assistant foreman
1 crane operator
1 crane foreman
4 carpenters—first class
2 carpenters—second class
2 to 4 carpenter helpers
2 to 6 laborers (largely local)

While the three-pile trestle construction has been applied to many bridge openings requiring but a few spans, it has been adapted also to bridges of considerable length. For example, the St. Francis overflow crossing is an open-deck steel beam-span trestle, 2,600 ft. long, while the bridge over the Black river near Corning, Ark., contains 101 panels of reinforced concrete slab spans occupying 1,800 lineal feet of bridge.

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